**UVVM Essential Mechanisms** –Quick Reference  
  
This document explains some of the essential mechanisms necessary for running UVVM, in addition to helpful and important VVC status and configuration records which are accessible directly from the testbench. A more comprehensive review can be found in the VVC Framework Manual.

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# Libraries

In order to use a VVC the following libraries need to be included:

library uvvm\_util;

context uvvm\_util.uvvm\_util\_context;

library uvvm\_vvc\_framework;

use uvvm\_vvc\_framework.ti\_vvc\_framework\_support\_pkg.all;

library bitvis\_vip\_<name>;

context bitvis\_vip\_<name>.vvc\_context;

# UVVM Initialization

The following mechanisms are required for running UVVM

|  |  |
| --- | --- |
| **Mechanism** | **Description** |
| **ti\_uvvm\_engine** | **ti\_uvvm\_engine**  This entity contains a process that will initialize the UVVM environment, and has to be instantiated in the testbench harness, or alternatively in the top-level testbench.  Example:  i\_ti\_uvvm\_engine : entity uvvm\_vvc\_framework.ti\_uvvm\_engine; |
| **await\_uvvm\_initialization()** | **await\_uvvm\_initialization(VOID)**  This procedure is a blocking procedure that has to be called from the testbench sequencer, prior to any VVC calls, to ensure that the UVVM engine has been initialized and is ready. This procedure will check the shared\_uvvm\_state on each delta cycle until the UVVM engine has been initialized.  Note that this method is depending on the ti\_uvvm\_engine mechanism.  Note that this method uses the t\_void parameter, defined in the UVVM Utility Library types package.  Example:  await\_uvvm\_initialization(VOID); |

# UVVM and VVC Shared Variables

UVVM and VVC shared variables are defined in global\_signals\_and\_shared\_variables\_pkg and the various vvc\_methods\_pkg, respectively.

Shared variables

|  |  |
| --- | --- |
| **Shared variable** | **Description** |
| shared\_uvvm\_status | Shared variable providing access to VVC related information via the info\_on\_finishing\_await\_any\_completion record element, i.e.  shared\_uvvm\_status.info\_on\_finishing\_await\_any\_completion  This record element gives access to the name, command index and the time of completion of the VVC that first fulfilled the await\_any\_completion(). The available record fields are:  vvc\_name : string -- default “no await\_any\_completion() yet”  vvc\_cmd\_idx : natural -- default 0  vvc\_time\_of\_completion : time -- default 0 ns  For more information regarding other fields available in the shared\_uvvm\_status see the UVVM Util QuickRef, section 1.4 |
| shared\_<vvc\_name>\_vvc\_config | Shared variable providing access to configuration parameters for each VVC instance and channel if applicable. E.g.  shared\_sbi\_vvc\_config(1).inter\_bfm\_delay.delay\_type := TIME\_START2START;  shared\_uart\_vvc\_config(RX,1).bfm\_config.bit\_time := C\_BIT\_TIME; |
| shared\_<vvc\_name>\_vvc\_status | Shared variable providing access to status parameters for each VVC instance and channel if applicable. E.g.  v\_num\_pending\_cmds := shared\_sbi\_vvc\_status(1).pending\_cmd\_cnt;  v\_current\_cmd\_idx := shared\_uart\_vvc\_status(TX,2).current\_cmd\_idx;  v\_previous\_cmd\_idx := shared\_uart\_vvc\_status(TX,2).previous\_cmd\_idx; |
| shared\_<vvc\_name>\_transaction\_info | Shared variable providing access to VVC instances transaction information to include in the wave view during simulation.  Available information is dependent on VVC type and typical information is:  operation : t\_operation; -- default NO\_OPERATION  data : std\_logic\_vector(C\_VVC\_CMD\_DATA\_MAX\_LENGTH-1 downto 0); -- default 0x0  msg : string(1 to C\_VVC\_CMD\_STRING\_MAX\_LENGTH); -- default empty |

# VVC Status, Configuration and Transaction information

The VVC status, configuration and transaction information records are defined in each individual VVC methods package.

Each VVC instance and channel can be configured and useful information can be accessed from the testbench via dedicated shared variables.

From the VVC configuration shared variable, one is given the ability to tailor each VVC to one’s needs, in addition to access the BFM configuration record via the bfm\_config identifier. In addition to BFM configuration possibility, the configuration settings consist of command and result queue settings, BFM access separation delay and a VVC dedicated message ID panel.  
Note that some BFMs require user configuration, e.g. the bit\_time setting in serial interface BFMs.

The VVC status shared variable provide access to the command status parameters for each of the VVCs, such as the current and previous command index, and the number of pending commands in the VVCs command queue. This provide a helpful tool, e.g. when synchronizing VVCs in the test sequencer using the await\_completion() or await\_any\_completion() methods.

When using a wave viewer during simulation, the transaction shared variable provides helpful information regarding current VVC operation and transaction information such as address and data. Note that the accessible fields depend on the VVC and its implementation. An example of two SBI VVCs performing FIFO write operations, followed by check operations, is shown in Figure 4‑1.



Figure 4‑1 VVC Transaction info example

# Direct Transaction Transfer – From VVCs and/or Monitors

UVVM now supports sharing transaction information in a controlled manner within the complete testbench environment. This allows VVCs and Monitors to provide transaction info to any other part of your testbench – using a predefined structured mechanism. This makes it even easier to make good VHDL testbenches.

Transaction information may be used in many different ways, but the main purpose is to share information inside the testbench of activity or accesses on a given DUT interface. Normally such information is provided from a dedicated interface monitor, but making such a dedicated monitor is sometimes quite time consuming and often not really needed. For that reason. UVVM provides a mechanism for getting the transaction information directly from the VVC.

## Purpose

The purpose of the direct transaction transfer is to allow a model or other part of the testbench to see exactly what accesses have been made on the various interfaces of the DUT, so that the expected DUT behaviour and outputs may be checked. Let us illustrate this with a really simple testbench scenario to verify a UART peripheral with an AXI-lite register/CPU interface on one side and the UART RX and TX ports on the other side. The test sequencer may command the AXI-lite BFM or VVC to write a data byte into the UART TX register, and then it must be checked that the data byte is transmitted out on the DUT TX output some time later.

1. A simple testbench approach could be to have the test sequencer also telling the receiving UART BFM or VVC exactly what to expect. This is a straight forward approach, but requires more action and data control inside the test sequencer. This could of course all be handled in a super-procedure, but for any undetermined behaviour inside the BFM or VVC, like random data generation or error injection, that would not work.
2. A more advanced approach is to have a model overlooking the DUT accesses, generate the expected data and tell the receiving BFM or VVC to check for that data
3. An even more advanced approach would be to use a Scoreboard to check received data (from DUT via VVC) against expected data from a model.

However, for the two latter approaches the model needs information about exactly what happened (the transaction) on the various DUT interfaces, so that it can generate the correct expected data. For the model it doesn’t matter if the transaction info comes from a monitor or from a VVC, as long as the information is correct.

The model could of course look at the interfaces and analyse the transactions itself, but distributing this task to the VVC or monitor makes the testbench far more structured and significantly improves overview, maintenance, extensibility and reuse – at least for anything above medium simple verification challenges.

Another purpose of providing transaction information is for progress viewing and debugging – typically via the wave view or simulation transcripts.

## Transaction definitions

By transactions we normally talk about a complete end to end transfer of data across an interface. This could be anything from a simple write, read or transfer of a single word - to a complete packet in a packet-oriented protocol like Ethernet. The word transaction is however also used for both sub-sets and super-sets of this – depending on the protocol and even on how we want to control our system or testbench. In order to communicate properly and to assure that transactions are properly understood, the following terms are defined:

* **Base transaction (BT)** is the lowest level of a complete transaction as allowed from the central sequencer.   
  E.g. AXI-lite read, write or check, UART transmit, receive or expect, Ethernet transmit, receive or expect
* **Sub-transaction (ST)** is the lowest level of an incomplete transaction as allowed from a BFM. The sub-transaction as such is complete seen from a handshake point of view, but the transfer of data is not complete. A split transaction protocol will typically have sub-transactions.  
  E.g. Avalon Read Request and Avalon Read Response
* **Leaf transaction (LT)** is not a transaction type in itself, but is the lowest level of complete **or** incomplete transaction defined for a given protocol. I.e. a sub-transaction when this is defined for a given protocol, otherwise a base transaction. This definition is needed in order simplify various explanations.  
  (e.g. for Avalon: LT = the sub transactions, and for UART, SBI or Ethernet: LT = the base transactions (as no sub-transaction exist for these protocols)
* **Compound transaction (CT)** is a set of transactions or other methods or statements that as a total is doing a more complex operation.   
  E.g. SBI\_Poll\_Until() or a UART transmit of N consecutive bytes.

## Transaction information

Information about the above transactions is typically provided to a model in the test harness. Depending on whether the transaction info is provided from the VVC or Monitor, different types of information will be available. Common for both is that they always provide info about the operation (read, write, transmit, etc) and often also any other protocol specific info. For a UART this could be data and parity, for an SBI it could be address and data, and for Ethernet: the packet fields.

This minimum is normally what the Monitor can provide from just analysing the interface, and this is also normally enough for a model to generate expected DUT outputs. The VVC on the other hand, can provide more info, which could be useful for instance for progress viewing and debugging.

The transaction information is organised as a transaction record with some predefined fields as shown below. The first table shows the general transaction record, whereas the second table shows a concrete example for the SBI.

Note that for a given interface/protocol, the VVC and the Monitor will use the same interface dedicated transaction record type – with some fields potentially unused.

Table 1 – General Transaction record t\_transaction. The greyed-out fields indicate optional or protocol dedicated fields

|  |  |  |
| --- | --- | --- |
| **Field name** | **Type name** | **Description** |
| Operation | t\_operation | Protocol operation on the given DUT interface. E.g. NO\_OPERATION, WRITE, READ, TRANSMIT, POLL\_UNTIL, …  NO\_OPERATION is default and thus used when there is no access. All operations will be separated with a NO\_OPERATION for at least 1 delta cycle, e.g. NO\_OPERATION – WRITE – NO\_OPERATION – READ – NO\_OPERATION. |
| <Optional protocol dedicated field(s)> | <Protocol dedicated> | One or more fields required to complete the transaction info E.g. for UART: Single field ‘data’; for SBI: field 1: ‘addr’, field 2: ‘data’; for Ethernet: Most ethernet fields as separate fields here – or a better solution include as a complete sub-record |
| Transaction\_status | t\_transaction\_status | Transaction status. Handled slightly different from a VVC and a Monitor. VVC: Will show ‘IN\_PROGRESS’ during the transaction and INACTIVE in between (for at least one delta cycle)  Monitor: Will show FAILED or SUCCEEDED immediately as soon as this is 100% certain – and keep this info for the display period defined in the Monitor configuration record, or until the next transaction is ready to be displayed. Other than that it will show INACTIVE (even when a transaction has started – before the transaction status is known) |
| VVC\_Meta | t\_vvc\_meta | Additional transaction information – only known by the VVC. So far ‘msg’ and ‘cmd\_idx’ (the free running command inde A monitor has no knowledge of this as and will set them to msg = “”, cmd\_idx = -1 |
| Error\_info | t\_error\_info | Any type of error injection relevant for the given protocol. Typically parity or stop-bit error in an UART or a CRC error in an Ethernet. If no error injection or detection has been implemented, this sub-record may be left out. |
| NOTES:  - For transaction info from a VVC the record reflects the command status, i.e. the status assumed by the VVC when initiating the command, whereas the Monitor will set up the record only after knowing whether the transaction has failed or succeeded. The VVC does not know the BFM status, and this is fine because the BFM will issue an alert for unexpected behavior. | | |

Table 2 – SBI specific Transaction record t\_transaction. The greyed-out fields indicate protocol dedicated fields

|  |  |  |
| --- | --- | --- |
| **Field name** | **Type name** | **Description** |
| Operation | t\_operation | Either of WRITE, READ or CHECK, but could also be POLL\_UNTIL or a more complex compound transaction |
| Address | unsigned |  |
| Data | std\_logic\_vector |  |
| Transaction\_status | t\_transaction\_status |  |
| VVC\_Meta | t\_vvc\_meta |  |
| Note: No error\_info field as no error injection or detection has been implemented in neither VVC nor Monitor – at this stage. | | |

Other interfaces will of course have different protocol dedicated fields, or even a complete protocol dedicated sub-record (e.g. for Ethernet packet fields)

## Transaction info transfer

In order to reduce the number of signals from a VVC or Monitor, all possible simultaneous transactions (and their transaction records) are collected into a single transaction group record.

For an SBI interface this will consist of a BT record and potentially a CT record, whereas for an Avalon it will in addition also consist of two ST records because for instance a read request may be active at the same time as a read response. (And the sub-transactions are part of a base transaction and may also be part of a CT).

Table 3 below shows the maximum transaction group record for an SBI, whereas Table 4 below shows the maximum transaction group record for an Avalon. The greyed-out CT is optional for both, and thus depends on whether CTs have been defined in the VVC. Multiple parallel STs may be written to the transaction group record simultaneously – as these are handled by different “threads” (concurrent statements like a process).

A Monitor cannot know about CTs, and thus a monitor will never fill inn that sub-record. A Monitor for a split transaction protocol (i.e. with multiple STs) may or may provide BT info. If it does, this should normally be implemented in a higher level “wrapper”

Note again:  
- A VVC will update its DTT leaf transaction details at the start of the transaction when the BFM is called. and turned off when BFM is finished.

- A monitor will set its DTT information after the transaction is finished (or transaction status is known) and keep it on for a pre-defined time – or until the next transaction is finished if earlier.

It is recommended that the model (or any other user of the DTT signals) triggers on transaction\_status changing to ‘INACTIVE’ (and then sample <signal>‘last\_value

Table 3 – Maximum transaction group record t\_transaction\_group – for an SBI interface

|  |  |  |
| --- | --- | --- |
| **Field name** | **Type name** | **Description** |
| bt | t\_transaction | Base transaction |
| ct | t\_transaction | Compound transaction |

Table 4 - Maximum transaction group record t\_transaction\_group – for an Avalon MM interface

|  |  |  |
| --- | --- | --- |
| **Field name** | **Type name** | **Description** |
| st\_request | t\_transaction | Sub-transaction |
| st\_response | t\_transaction | Sub-transaction |
| Bt | t\_transaction | Base transaction |
| ct | t\_transaction | Compound transaction |

## Transaction info transfer signals

The DTT (Direct Transaction Transfer) is provided out of the VVC and Monitor using global signals. These signals and all DTT related VHDL types are defined in transaction\_pkg..

- Monitor DTT signal : global\_<protocol-name>\_monitor\_transaction, e.g. global\_uart\_monitor\_transaction

- VVC DTT signal: global\_<protocol-name>\_transaction, e.g. global\_uart\_transaction. The VVC is also responsible for filling out the vvc\_meta record field.

# Protocol aware Error Injection

Error injection into the DUT could be very useful in a testbench in order to test how the DUT handles interface errors when these errors are a) to be detected and corrected, b) detected only, and c) not detected but may or may not affect the behaviour. Protocol aware error injection is defined here as intelligent error injection, given knowledge about the interface and protocol, e.g. to inject a parity error in a protocol rather than just inverting or delaying a signal without pre-defined detailed support to do this at the right place. The latter is supported by a dedicated “brute force” error injection VIP ‘bitvis\_vip\_error\_injection’ in UVVM.

UVVM has a pre-defined methodology for handling protocol aware error injection in a structured way.

**Note that only some VVCs and BFMs currently support error injection. The principles shown for these VVCs and BFMs may be applied directly also for user defined VIP.**

## UVVM error injection principles

Error injection may be applied randomly, with no limitations. For UVVM however, we recommend the following approach:

1. No randomisation of behaviour inside BFMs when this could affect the DUT behaviour or output. (and a monitor would be required to check the actual DUT stimuli.)  
   Hence BFM procedures should only be called with parameters explicitly defining the interface behaviour (from the BFM side). Thus no parity error randomisation inside.  
   The only exception is for behaviour that should not affect the DUT. Thus the position of a data bit error could be randomised inside the BFM.
2. It is recommended that more advanced VVC include randomisation – in order to distribute this away from the test sequencer and increase the re-use value of a VVC.  
   Thus a VVC may be told to apply say 10% parity errors for a UART\_VVC transmission into the DUT. In that case the VVC will randomly – with a 10% probability - inject a parity error into the DUT. As the VVC uses a BFM to handle the actual interface/protocol, this means that in 10% of the BFM transmit calls the VVC will request a parity error to be injected.

## Error injection in BFMs

In order to simplify the specification of which errors to inject, the complete error injection specification is given as a sub-record inside the BFM configuration.

E.g. inside the UART BFM configuration the following sub-record is defined – with fields specifying the error injection details (Details given in the UART VIP doc)

* error\_injection (fixed name, but type will differ)
  + - parity\_bit\_error (boolean)
    - stop\_bit\_error (boolean)

In order to initiate error injection, the BFM config record must be modified and included in the BFM procedure call

## Error injection in VVCs

In order to simplify the specification of which errors to inject, the complete error injection specification is given as a sub-record inside the VVC configuration (Note: not the BFM config)

E.g. inside the UART VVC configuration the following sub-record is defined – with fields specifying the error injection details (Details given in the UART VIP doc)

* error\_injection
  + - parity\_bit\_error\_prob (real between 0.0 and 1.0)
    - stop\_bit\_error\_prob (real between 0.0 and 1.0)

In order to initiate error injection, the VVC config record must be assigned the wanted values via the VVC configuration shared variable. (see ch 4)

Note that the Error injection sub-record inside the VVC configuration will override that of the BFM configuration.

Any compound or more advanced transactions may of course also request error injection directly or indirectly via the VVC command itself.

## Naming and type usage

The error injection sub-record will be VVC and BFM dedicated, and thus any names and types may be used, and even sub-records under ‘error\_injection’ is required. The VVC and BFM error injection records may differ or be the same. The only requirement is that readability is prioritised. Values should be checked against legal ranges or values.

# Randomisation

UVVM provides functions and procedures for simple generation of random numbers (real, integer, time) and vectors. This is described in detail in the documentation for the UVVM Utility Library. Other libraries for generation of random data may also be used seamlessly with UVVM.

**Note that only some VVCs currently include randomisation (e.g. \*\*\*\*\*.) The principles shown for these VVCs may be applied directly also for user defined VIP.**

## UVVM VIP randomisation principles

Randomisation may of course be applied with no limitations in a UVVM based testbench. For UVVM VIP however, we recommend the same general approach as for error injection randomisations:

1. No randomisation of data inside BFMs as this would affect the DUT behaviour or output. . (and a monitor would be required to check the actual DUT stimuli.)  
   Hence BFM procedures should only be called with explicit data.
2. It is recommended that more advanced VVCs include functionality for randomisation of data – in order to distribute this away from the test sequencer and increase the re-use value of a VVC. Thus, a VVC may be told to apply random data, in which case the VVC will randomly generate data according to a given profile (e.g. uniform) and provide that data to the interface via the BFM call. The profile and constraints will depend on the needs and the VVC implementation

## Data randomisation in BFMs

There is no data randomisation inside a normal BFM, for the reason given above.

## Data randomisation in VVCs

A VVC may be commanded to generate constrained random data, where data in this sense could also be addresses, lengths, etc. Typically such commands would allow flexibility for the number of accesses and other important aspects – like scoreboards, common buffers, files, etc.

A few randomisation profiles have been predefined both as typical use cases and as examples for future extensions, when needed.

|  |  |
| --- | --- |
| RANDOM | Uniform distribution |
| RANDOM\_FAVOUR\_EDGES | Significantly more edge cases, where “edge” differs between various interfaces.  E.g. UART: Cover patterns like 01111111, 00000000, 11111111, 11111110, 01010101, 10101010, |
| Flere???? |  |
| <user-defined> |  |

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## VVC Command Syntax

Randomisation is defined by the following maximum number of parameters – immediately following the VVC dedicated parameters (like address for the SBI):

|  |  |  |
| --- | --- | --- |
| Number of repetitions (protocol accesses) | Randomisation profile (as shown above) | Optional: \*\*\* rand  0= no \*\*\*\* |

# Functional Coverage

External libraries for handling functional coverage be used seamlessly with UVVM. The only exception here is that log and alert messages will go to a different file set.

**Note that only some VVCs currently include functional coverage (e.g. \*\*\*\*\*.) The principles shown for these VVCs may be applied directly also for user defined VIP.**

## UVVM VIP Functional Coverage principles

Functional coverage may of course be applied with no limitations in a UVVM based testbench. For UVVM VVCs however, we recommend to structure this as follows:

1. For advanced testbenches using functional coverage, it is recommended to include as much of this functionality in the VVCs as possible – in order to distribute this away from the test sequencer and increase the re-use value of a VVC.
2. A VVC may be told to apply functional coverage either on the master/transmitter side or the slave/receiver side – or both, all depending on how the functional coverage is applied and utilised inside the testbench. In any case the VVC will receive a command to start or modify a predefined functional coverage task.  
   (An example on how functional coverage is applied and used to terminate a test section when sufficient functional coverage is reached in the receiver, is shown in the UART VVC.)

## Functional Coverage in VVCs

A VVC may be commanded to just gather functional coverage and potentially flag when required coverage is achieved, or to keep on doing something (like receiving or transmitting data) until the requested coverage is reached.

A few functional coverage profiles have been predefined both as typical use cases and as examples for future extensions, when needed.

|  |  |
| --- | --- |
| COVERAGE\_FULL | Full coverage meaning all possible permutations |
| COVERAGE\_EDGES | A predefined set of important edge cases – for instance like the RANDOM\_FAVOUR\_EDGES in the previous chapter. |
| Flere???? |  |
| <user-defined> |  |

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# VVC parameters and sequence for Randomisation, Functional Coverage, Sources and Destinations

# Multiple Central Sequencers

A structured test environment is important and we recommend the use of a test harness to instantiate VVCs, DUT, clock generator and so forth. The testbench may consist of one or more test sequencers which are used to control the complete testbench architecture with any number of VVCs, although for a better testbench overview we recommend to have a single central test sequencer only.

# Compile scripts

In the script folder in the root directory the compile\_all.do compiles all UVVM components. This script may be called with one to three input arguments. The first input argument is the directory of the script folder at the root directory from the working directory. The second input argument is the target directory of the compiled libraries, by default every library is compiled in a sim folder in the corresponding components directory. The third input argument is the directory to a custom component list in .txt format. The script will only compile the components listed in that file. By default, the script uses the file component\_list.txt located in uvvm/script. This file can be modified so that only some components are compiled.

Example: do uvvm/script/compile\_all.do uvvm/script

There are also compile scripts for all UVVM components located in the script folder of each UVVM component. These scripts can be called with two input arguments. The first input argument is the directory of the component folder from the working directory. The second input argument is the target directory of the compiled library, default is the sim folder in the respective component.

Example: do uvvm/uvvm\_util/script/compile\_src.do uvvm/uvvm\_util

# Scope of verbosity control

Message IDs are used for verbosity control in many of the procedures and functions in UVVM, as well as log messages and checks in VVCs, BFMs and Scoreboards.   
Note that VVCs and Scoreboards comes with dedicated message ID panels and are not affected by the global message ID panel, but accessed by addressing targeting VVC or Scoreboard and, if applicable, instance number or with a broadcast.

E.g.

-- Global message ID panel. Does not apply to VVCs or Scoreboards, as they have their own local message ID panel

disable\_log\_msg(ALL\_MESSAGES);

enable\_log\_msg(ID\_SEQUENCER);

-- VVC message ID panel  
disable\_log\_msg(VVC\_BROADCAST, ALL\_MESSAGES); -- broadcast to all VVCs and instances

enable\_ log\_msg(I2C\_VVCT, C\_VVC\_INSTANCE\_1, ID\_BFM\_WAIT); -- I2C VVC instance 1  
enable\_log\_msg(I2C\_VVTC, C\_VVC\_INSTANCE\_2, ID\_BFM\_WAIT); -- I2C VVC instance 2

-- Scoreboard message ID panel

shared variable sb\_under\_test : record\_sb\_pkg.t\_generic\_sb;

…

sb\_under\_test.disable\_log\_msg(ALL\_INSTANCES, ID\_CTRL); -- broadcast to all SB instances

sb\_under\_test.enable\_log\_msg(C\_SB\_INSTANCE\_1, ID\_DATA); -- SB instance 1

A subset of message IDs is listed in UVVM Utility Library QR, section 1.10.

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